Brake System

The present invention relates to a brake system of the 'brake-
by-wire' type for actuating a motor vehicle brake system
comprising a brake booster which is operable in response to
the driver's wish both by means of a brake pedal and by means
of an electronic regulating and control unit, with a means
being provided to decouple a force-transmitting connection
between the brake pedal and the brake booster in the 'brake-
by-wire' operating mode, a master brake cylinder connected
downstream of the brake booster in terms of effect, to the
pressure chambers of which wheel brakes of the motor vehicle
are connected, a pedal travel simulator which interacts with
the brake pedal and due to which a resetting force acting on
the brake pedal can be simulated in the 'brake-by-wire'
operating mode independently of an actuation of the brake
booster, and which can be enabled in the 'brake-by-wire'
operating mode when the force-transmitting connection between
the brake pedal and the brake booster is decoupled and can be
disabled outside the 'brake-by-wire' operating mode, a first
sensor to sense the brake pedal actuating travel, a second
sensor to sense the travel of an output member (push rod) of
the brake booster, and a third sensor (i.e. a pressure sensor)
to sense the brake pressure prevailing in the system, the
signals of which sensors are sent to the electronic regulating
and control unit.

A brake system of this type is disclosed in the applicant's international patent application WO 2004/005095. It can be taken from the disclosure of the mentioned patent application that the electronic regulating and control unit initiates appropriate safety procedures, in particular a hydraulic fallback mode, on account of detected deviations between preset nominal values and actual values measured by means of the sensors. However, no hints can be taken from the document as to how failure of the hydraulic fallback mode being caused e.g. by the inclusion of air or the occurrence of leakages in the system, can be recognized by the driver or detected by the system, respectively.

In view of the above, an object of the invention is to disclose measures in a brake system of the type mentioned hereinabove, which render it possible to compensate increased pressure fluid volume absorption in the case of a fault, which is caused by e.g. the inclusion of air or a brake circuit failure, by using control technique means.

A first solution of this object involves that the electronic regulating and control unit includes a control circuit for controlling the travel covered by the output member of the brake booster, the nominal value thereof being calculated corresponding to the actuating travel of the brake pedal, with a monitoring module being provided which, in the case of a fault such as the inclusion of air or brake circuit failure, performs a partial compensation of the extension of the travel covered by the output member of the brake booster, which extension is caused by the fault.

A second solution of the object referred to hereinabove
involves that the electronic regulating and control unit
includes a control circuit for controlling the travel covered
by the output member of the brake booster and the hydraulic
pressure prevailing in the system, the nominal values thereof
being calculated corresponding to the actuating travel of the
brake pedal, with a monitoring module being provided which, in
the case of a fault such as the inclusion of air or brake
circuit failure, switches the control circuit from the travel
control mode to the pressure control mode in order to perform
a compensation of the extension of the travel covered by the
output member of the brake booster, which extension is caused
by the fault.

In a favorable improvement of the first solution of the
invention, the partial compensation of the extension of the
travel covered by the output member of the brake booster,
which extension is caused by the fault, is performed by adding
a correction value to the nominal value.

In another favorable embodiment of the subject matter of the
invention, a pressure fluid volume/pressure characteristic
curve is stored in the monitoring module, i.e. the dependency
of the pressure fluid volume absorption of the brakes or of
the travel covered by the output member of the brake booster
and corresponding to the pressure fluid volume absorption on
the hydraulic pressure (p) Q or $S_{Ds} = f(p)$, and the monitoring
module is furnished with the actual values of the travel
covered by the output member of the brake booster and of the
hydraulic pressure prevailing in the system, and a travel
value corresponding to the nominal value of the pressure fluid

volume is calculated from the actual pressure value and
compared with the actual value of the travel covered by the
output member of the brake booster, and a fault in the system
is concluded when the comparison result exceeds a threshold
value.

The above-mentioned correction value can preferably correspond
to half the result of the comparison.

In another advantageous improvement of the subject matter of
the invention, the control quality is considerably enhanced in
that the actual values undergo a low-pass filtering operation.

In another favorable feature of the invention, a transition
function, e.g. low-pass filtering or a ramp function, is
activated when a case of fault is detected.

It is furthermore provided according to another feature of the
invention that a warning lamp is activated when a case of
fault is detected in the system.

Further features and advantages of the invention will be
explained in detail in the following description by way of two
embodiments, making reference to the accompanying drawings. In
the drawings:

Figure 1   is a schematic view of the brake system of the
           invention;

Figure 2   shows a block diagram of a first design of a control
           circuit of the invention;

Figure 3   shows a block diagram of a second design of a control
            circuit of the invention; and

Figure 4   shows a diagram view of the mode of operation of the
            second design of the control circuit shown in Figure
            3.

The brake system shown in a schematic view in Figure 1 and
intended for the actuation of a motor vehicle brake system of
the 'brake-by-wire' type essentially comprises a brake
booster, preferably a vacuum brake booster 3, a master brake
cylinder connected downstream of the brake booster 3,
preferably a tandem master cylinder 4, to the pressure
chambers (not shown) of which wheel brakes 13, 14, 15, 16 of a
motor vehicle are connected by the intermediary of a hydraulic
control unit 17, a pressure fluid tank 5 associated with the
master brake cylinder 4, a brake pedal 1 for actuation of the
brake booster 3 by the driver, a pedal travel simulator 2
which cooperates with the brake pedal 1, in particular in the
'brake-by-wire' operating mode and imparts the customary brake
pedal feel to the driver, at least one sensor device 6 for
sensing a driver's deceleration request or the actuating
travel S_{Bp} of the brake pedal 1, as well as an electronic
control unit 7, the output signals of which enable, among
others, actuation of an electromagnet 8 that is associated
with the brake booster 3 and renders it possible to actuate a
pneumatic control valve 9 independently of the driver's wish,
the said control valve controlling the supply of air to the
brake booster 3. As will be explained in detail in the
subsequent description, the electronic regulating unit 18

comprises a control circuit for controlling a characteristic
quantity of the brake booster 3, preferably the travel S_{Ds}
covered by the output member 20 of the brake booster 3, or for
controlling the mentioned quantity and the hydraulic pressure
prevailing in the system.

An axial slot 'a' provided between the end of a piston rod 10
coupled to the brake pedal 1 and a control piston 11 of the
above-mentioned control valve 9 ensures decoupling the force-
transmitting connection between the brake pedal 1 and the
brake booster 3 in the 'brake-by-wire' operating mode. A
travel sensor 18 is used to sense the travel of a movable wall
19 that generates the boosting force of the brake booster 3
or, respectively, the travel (S_{Ds}) of an output member 20 of
the brake booster 3 which transmits its output force onto a
non-illustrated first piston of the master brake cylinder 4.
Besides, a pressure sensor 21 is integrated into the hydraulic
control unit 17 and senses the hydraulic pressure (p)
prevailing in the system.

The pedal travel simulator 2 by which, as has been mentioned
above, a resetting force acting on the brake pedal in the
'brake-by-wire' operating mode can be simulated irrespective
of an actuation of the brake booster 3 is designed in such a
fashion that it can be enabled in the 'brake-by-wire'
operating mode when the force-transmitting connection between
the brake pedal 1 and the brake booster 3 is decoupled, and
can be disabled outside the 'brake-by-wire' operating mode.
The pedal travel simulator 2 is actuated by means of an
actuating member 12 articulated at the brake pedal 1.

The first design of the above-mentioned control circuit for controlling the travel S_{Ds} covered by the output member 20 of the brake booster 3 is illustrated in Figure 2 and basically comprises a nominal-value generating module 22, a travel controller 23, and a monitoring module 24. In the nominal-value generating module 22, the nominal value $S_{Dsnominal}$ of travel S_{Ds} covered by the output member 20 of the brake booster 3 is calculated from the actuating travel S_{Bp} of the brake pedal 1 detected by means of the travel sensor 6. The nominal value $S_{Dsnominal}$ to which a correction value S_{corr} calculated in the monitoring module 24 is added in an adder 25, is compared with the actual value $S_{Dsactual}$ of the travel covered by the output member 20 of the brake booster 3, which actual value is detected by means of the travel sensor 18, whereupon the deviation ΔS calculated this way is sent to the travel controller 23 whose output quantity, an electric voltage U, drives the electromagnet 8. The monitoring module 24, in which a pressure fluid volume/pressure characteristic curve is stored, i.e. the dependency of the pressure fluid volume absorption of the brakes 13 to 16 or of the travel S_{Ds} covered by the output member (20) of the brake booster 3 and corresponding to the pressure fluid volume absorption on the hydraulic pressure (p) Q or $S_{Ds} = f(p)$, is provided as input quantities with the actual values $S_{Dsactual}$, p_{actual} of the travel covered by the output member 20 of the brake booster 3 and of the hydraulic pressure prevailing in the system, which preferably undergo a low-pass filtering operation in associated low-pass filters 26, 27. A travel value S_{model} corresponding to a nominal value of the pressure fluid volume is calculated from the actual pressure value p_{actual} in the monitoring module 24 and compared with the actual value $S_{Dsactual}$

of the travel covered by the output member 20 of the brake booster 3. When the comparison result $\Delta S_{diff} = S_{model} - S_{Dsactual}$ exceeds a threshold value $S_{threshold}$, the above-mentioned correction value S_{corr} is generated which e.g. corresponds to half the value $\Delta S/2$ of the deviation ΔS sent to the travel controller 23. An optical warning, for example, by a warning lamp 31 lighting up, can be produced simultaneously. Addition of the correction value S_{corr} achieves a partial compensation of the extension of the travel $S_{Dsactual}$ covered by the output member 20 of the brake booster 3, which extension is e.g. caused by gas inclusions in the system or a brake circuit failure.

In the second design of the control circuit illustrated in Figure 3, a nominal-pressure-value generating module 28 is provided in addition to the nominal-travel-value generating module 22 mentioned with respect to Figure 2, in which the nominal value $p_{nominal}$ of the hydraulic pressure prevailing in the system is calculated from the actuating travel S_{Bp} of the brake pedal 1 that is detected by means of the travel sensor 6. While the nominal travel value $S_{Dsnominal}$, like in the first design, is compared with the actual travel value $S_{Dsactual}$ in order to produce the deviation ΔS, a second deviation Δp is produced in a second adder 29 from the nominal pressure value $p_{nominal}$ and the actual pressure value p_{actual}. The two deviations ΔS, ΔP are sent to a switch-over device 30 which, in response to the signal $S_{corr} > 0$ (switch-over condition), switches over from the travel control mode as a standard mode of operation to a pressure control mode. As this occurs, the controller 23 arranges for different parameters for the travel control and the pressure control.

In order to prevent an abrupt change of the controlled
variable in the second design of the control circuit, a
transition function, e.g. low-pass filtering or a ramp
function, is activated at the time t_1 (point A of the
characteristic curve - end of the travel control) of the
switch-over operation. This procedure is illustrated in Figure
4, and the characteristic curve $p = f(t)$ characterized by I
corresponds to the travel control mode, while the
characteristic curve designated by II corresponds to the
pressure control mode, and portion A - B corresponds to the
transition function. It becomes apparent from the illustration
that starting with the time t_2 (point B of the characteristic
curve) the control follows the pressure control characteristic
curve. The vertical shift L between the two characteristic
curves I and II is caused by gas inclusions or leakages, for
example.